DOCUMENT RESUME

ED 265 797 CE 029 836

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TITLE	Solar Energy Usage.
INSTITUTION	Pittsburg State Univ., Kans. Kansas Vocational Curriculum and Research Center.
SPONS AGENCY	Kansas State Dept. of Education, Topeka. Div. of Vocational Education.
PUB DATE	Jun 81
CONTRACT	81-133-10
NOTE	48p.: For related documents see CE 029 829-838.
AVAILABLE FROM	Kansas Vocational Curriculum Dissemination Center, Pittsburg State University, Pittsburg, KS 66762 ($2.50).
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Behavioral Objectives; Conservation Education; Energy; Energy Conservation; *Heating; Learning Activities; Postsecondary Education; *Power Technology; Secondary Education; *Solar Radiation; Student Developed Materials; Tests; Transparencies; Units of Study; Vocational Education
IDENTIFIERS	Energy Consumption

ABSTRACT

This instructional unit is one of 10 developed by students on various energy-related areas that deals specifically with solar energy use. Its objective is for the student to be able to discuss the broad aspects of solar energy use and to explain the general operation of solar systems. Some topics covered are availability and economics of solar energy, active solar systems, and auxilliary energy systems. Material in each unit may include some or all of the following: terminal and specific objectives, list of references, information sheet with terms and definitions, informative materials, transparency masters, assignment sheet(s), and unit tests with answers. (YLB)

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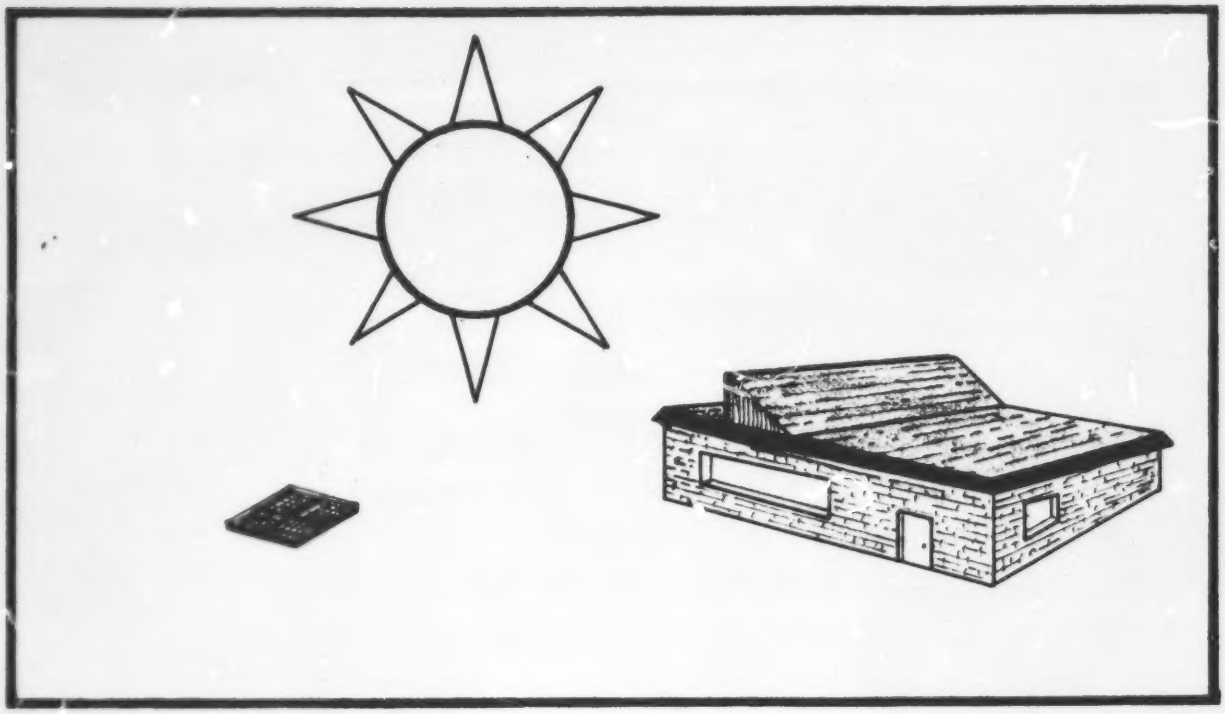
SOLAR ENERGY USAGE



by

Ron Crank

Funded by
The Vocational Education Administration Section
Kansas State Department of Education
Contract #81-133-10

Produced by
Kansas Vocational Curriculum Dissemination Center
Pittsburg State University
Pittsburg, KS
June 1981

CE 029 836

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SOLAR ENERGY USAGE

TERMINAL OBJECTIVE

Upon completion of this unit the student will be able to discuss the broad aspects of solar energy use and to explain the general operation of solar systems. Proficiency will be evidenced by a recommended 85 percent accuracy on unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit the student will be able to:

1. Identify factual information from non-factual information concerning solar energy usage.

2. Discuss four factors that contribute toward the high desirability of solar energy as a resource.

3. Discuss three factors that have interfered with exploitation of solar energy as a resource.

4. Discuss three factors that affect the solar radiation striking the surface of the earth.

5. Describe the basic components of a solar water heating unit and explain the operational difference between a "free" and a "forced" system.

6. List three means by which energy is transferred from one medium to another.

7. Match terminology with correct definitions concerning solar energy.

8. Discuss the difference between and an active and a passive solar system.

SOLAR ENERGY USAGE

INFORMATION SHEET

I. Terms and definitions

A. Active solar system -- An assembly of collectors, thermal storage device(s), and transfer fluid which converts solar energy into thermal energy, and in which energy in addition to solar is used to accomplish the transfer of thermal energy.

B. Auxiliary energy subsystem -- Equipment utilizing energy other than solar both to supplement the output provided by the solar energy system, and to provide full energy backup during periods when the solar domestic hot water systems are not operating.

C. Collector, flat-plate -- The type of solar collector generally used in solar hot water systems.

D. Collector subsystem -- The assembly used for absorbing solar radiation, converting it into useful thermal energy, and transferring the thermal energy to a heat transfer fluid.

E. Component -- An individually distinguishable product that forms part of a more complex product (i.e., subsystem or system).

F. Conduction -- Transmission of heat by passage of energy from particle to particle.

G. Convection -- Transfer of heat by circulation of liquid or gas.

H. Control subsystem -- The assembly of devices used to regulate the processes of collecting, transporting, storing and utilizing solar energy.

I. Design life -- The period of time during which a domestic hot water system is expected to perform its intended function without requiring major maintenance or replacement.

J. Green House -- Any structure which is constructed of glass, plastic, or any other material which allows the sun's rays to pass through. In the past, these structures were constructed to grow plants so that the heat from the sun could be utilized all year around.

K. Heat exchanger -- A device for transferring thermal energy from one fluid to another.

L. Heat transfer fluid -- A liquid which is used to transport thermal energy.

M. Insolation -- Rate at which solar energy is received on a horizontal surface.

N. Langley -- Conventional measure of solar radiation equal to 4 BTU's per square foot.

O. Latent heat -- Amount of heat energy released when gas is condensed to liquid or liquid is changed to solid without change of temperature.

P. Passive solar system -- An assembly of natural and architectural components including collectors, thermal storage device(s) and transfer fluid which converts solar energy into thermal energy in a controlled manner and in which no pumps are used to accomplish the transfer of thermal energy.

Q. Radiation -- Process in which energy in form of rays of light or heat is sent out from atoms and molecules as they undergo intermal change.

R. Solar building -- A building which utilizes solar energy by means of an active or passive solar system.

S. Solar constant -- Average intensity of solar energy striking earth's atmosphere measured on plane - perpendicular to its path.

T. Solar degradation -- The process by which exposure to sunlight deteriorates the properties of materials and components.

U. Solar domestic hot water system -- The complete assembly of subsystems and components necessary to convert solar energy into thermal energy for domestic hot water in combination with auxiliary energy when required.

V. Storage subsystem -- The assembly used for storing thermal energy so that it can be used when required.

W. Subsystem -- A major, separable, functional assembly of a system so that it can be used when required.

X. Thermal energy -- Heat possessed by a material resulting from motion of molecules which can do work.

Y. "Tilt" of solar collector -- Latitude of site plus 15°.

Z. Trombe wall - A wall of concrete, brick, concrete block, or water enclosed in containers to absorb and reradiate energy so as to act as a moderator of heat. A thermal storage wall.

II. References:

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D. "Solar Hot Water and Your Home". National Solar Heating and Cooling Center Publication: Rockville, Maryland.

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SOLAR ENERGY USAGE

Humans have always looked to the sun for heat. It was the only source of warmth during the many thousands of years of fireless existence. Early fires were inefficient and therefore the sun was a major source of heat and light until just a few hundred years ago.

Early solar heating was free of technology. Our predecessors took the heat from the sun when and where it was available. In recent generations our society has become accustomed to heated rooms and water for comfort. We also have become use to relief from the sun's heat in air-conditioned houses, offices, cars and even our sports facilities. To accomplish the control, we have relied on electrical or fuel burning furnaces, water heaters and air conditioners.

The use of solar has existed for several years; solar water heaters in Florida in the 1930's and evaporative coolers for air-conditioning in the southwestern parts of the United States. The backyard clothesline still most efficiently dries the family laundry in relation to the automatic clothes dryer fueled by gas or electricity.

The rapidly rising cost of fossil fuels and their supply and difficulty in recovery have caused a return to solar considerations for energy use. The support of the federal government for research and development and the incentives for individual installations are proof of a new age. An age of solar technology and less dependence on non-renewable resources for energy production and consumption.

Solar technology is today concentrated in the areas of passive and active solar heating and cooling plus the conversion of the sun's rays to electricity. We will explore the application of these methods

in discussing the uses of solar energy.

First let us explore the availability and economics of the sun's energy. The major advantage of the use of solar energy is the amount of the overall resource. Energy, if measured by kilowatts of electrical use from the sun, would equal about 4 kilowatts per hour per meter. The energy equivalent of ten barrels of oil falls on each U.S. acre per day. This means that solar energy potential reaching the 2310 million acres of the contiguous U.S. states is equal to 22.4 billion barrels of oil or almost four times our present yearly oil consumption. This means that the overall resource base is more than adequate to supply the technological ability to utilize the solar power. The amount of solar energy will vary at any given time based on location. The solar rate of intensity is greatest when the sun is directly overhead. At other times the rate of sunlight is dependent on the angle at which radiation is striking the earth. The rate at which solar energy is received on the earth's surface is called insolation.

Insolation varies with the latitude, the time of day and the season of the year. More at noon and during summer verses less at early or late day and in the winter. At any given time only about half the earth is receiving any direct radiation at all. The chart on page indicates the rate of sunlight in parts of the contiguous United States.

The conventional method of solar radiation measurement is called "langley" or equal to one calorie per square centimeter or four BTU's per square foot. Therefore, the major portion of Kansas would receive 162 langleys annually while southern Arizona would receive 201 annually and only 115 per year in northern Maine by comparison.

Not all of the radiation striking the atmosphere continues directly to the earth. Some rays are reflected back into space or absorbed. Others are reflected back and forth a number of times before reaching earth as diffuse radiation. Variation in the radiation levels of sunlight are unpredictable due to weather and atmospheric conditions. Air pollution adds to the diffusion or tends to block the passage of radiation through the atmosphere of the earth. The maximum intensity of solar radiation at the earth's surface is about 1.2 kilowatts per square meter. This highest level occurs on clear days at low latitudes around noontime. The total energy received at a particular location averages 6 to 8 kilowatt hours per square meter per day.

When all the losses of radiation are accounted for the amount of solar energy actually received by the United States is about six hundred times the amount of energy it uses. In theory if solar energy were utilized at the rate of only 25% efficiency the available energy would be 150 times the amount of energy used in the average year.

The abundance of solar energy is adequate for current and future needs. The amount of radiant energy is not without some drawbacks, however. The rays of the sun are diluted and must be collected over large areas to be effectively utilized. Also, the solar radiation is intermittent, or varies due to time and season, and must be stored so it will be available for use when needed. Small scale projects are quite feasible but the seriousness of collection problems increase with the scale or size of the particular project.

One of the oldest uses of solar energy on a small scale is the drying of foods. The materials to be dried were spread out in the

sunshine without regard for dirt, insects or decay in the past. Current techniques are more aware of sanitation needs while utilizing the energy of the sun. The current technology uses solar collectors which supply hot air to drying units. These dehydration units are relatively inexpensive to construct and produce a product with high quality type results.

One of the obvious advantages of this type simple solar energy unit is the better utilization of food in the developing nations. Other simple solar uses of energy include: solar evaporation for production of salt utilized where evaporation exceeds the annual rainfall. The evaporation of ponds in industrial situations, where this method may be simple and effective, does create a potential hazzard to migratory waterfowl. The most widespread and successful use is found in domestic water heating for solar energy.

The most ideal conditions for the use of solar heat is in an area between 45° N latitute and 45° S latitude. These areas have more than 2000 hours of sunshine per year and are the most potential locales for solar water heating. This area includes most of the world's people excluding those living in Canada, Northern Europe and parts of northern U.S.S.R.

The heating of water by solar method, for family use, is currently used extensively in Australia, Israel, Japan and is in some limited use in parts of the United States.

ACTIVE SOLAR SYSTEMS

The basic water heating unit has several basic characteristics in common: A collecting surface with an area ranging from one to three square meters in size, an insulated storage tank and pipes for circulating the water from collectors to point of use. This basic

type unit requires minimal maintenance and is capable of supplying hot water at temperatures up to 98°c (200°F).

There are two basic types of fluid circulation systems, the "Free" system and the "Forced" system. Both systems utilize nonfreezing heat transfer fluid to prevent water from freezing in collector in winter usually ethylene glycol. All of the parts for constructing the systems and complete whole systems are available commercially. The heat provided by most systems is low grade heat running in the 100-140 degrees Fahrenheit range. This means that backup heating source is required to maintain a constant temperature of over 150° Fahrenheit in a domestic hot water tank. A thermostatically controlled electric coil or gas burner is usually added to the system to provide the necessary backup heat.

The "Free" system also known as the free-connection, gravity or thermosyphon system movement is induced by the difference in density between different parts of the fluid. Heated fluid is less dense than the colder fluid and tends to rise. The naturally circulating collector storage loop is made possible with the proper positioning of the systems components parts. The thermosyphoning action requires that the storage tank be at least one foot above the collector unit. Larger than normal plumbing fixtures must be used to reduce the amount of pipe friction losses in smaller pipe. The flow rate is about one gallon per foot per hour in the bright sunlight. The "Free" system requires that the storage tank be placed above the collector when installing the system.

In the "Forced" system some additional components are needed to operate the system. They include a pump, motor and pump controller

which turns on the pump when the temperature of the water of collector is several degrees higher than the temperature of water in the tank bottom. For a single family unit, the solar water heater requires a 1/12 h.p. pump usually to move water through the system. It is important to prevent reverse cycling in both the free and forced systems when the heating systems are turned off. The cooling cycle occurs when circulation fluid loses energy usually through a collector at night. A simple check valve, like those used on sump pump lines, permits the water flow in only one direction preventing reverse circulation and the nighttime thermal loss from the collector.

The considerations a typical consumer must allow in choosing a solar water heating system are few and simple: the geographic location of the home and number of langley's received yearly, the efficiency of the system in providing the sufficient amount of heated water, the design of the home and any necessary structural modifications that may be required. More specific information to consider would include the systems durability and its resistance to weather, ease of repair if something goes wrong, cost of repairs if needed, and protection against corrosion to avoid any serious health problems from direct use of the water from the system. The three most commonly used metals in collectors are copper, steel and aluminum. Chemicals are usually added to prevent corrosion in most systems. Copper will work over a long period without the need of corrosion inhibitors but steel and aluminum may fail quickly without special protection. With specially treated water, all three types will last indefinitely as long as the water treatment is maintained. Protection against leaks is greater as the number of joints in the

plumbing system and therefore greater chance of leakage. Some liquid collectors using chanel systems have reduced the need for soldered joints considerably without any effect on system efficiency. Insulation of pipes, ducts, and back parts of the collectors and storage tank are necessary to prevent heat loss. This is true of both inside and outside pipes and ducts.

The pitch of the pipes has to be positive so water cannot collect in places that could potentially freeze. Fans and pumps used in forced systems use energy and therefore should be no bigger than necessary to perform the task efficiently. A time elapsed meter can be included in the installation to see that fans or pumps are not running for too long a period. A bleeding mechanism is necessary because of the habit of air getting into the system even though they are watertight. An expansion tank or room for storage expansion should also be included. Controls and valves should be corrosive resistant and as silent as possible. If possible the controls and valves should be brass when involved in a potable water supply situation.

Remember the system has to last for many years and the workmanship cost would be the same or less prone to fail if the best materials are used. All installations should be done in a throughly workmanlike manner. With good workmanship of high quality, any unnecessary leaks and malfunctions will be less likely to happen.

In summary, the important points to consider in acquiring a solar water heating system are as follows: The total cost of the system in labor, quality materials, the expected performance of the system all year around, and the expected lifetime of the system.

The best method to buy solar and receive your money's worth is to avoid several major obstacles. One is lack of knowledge and experience on the part of the consumer. Second is the existence of some manufacturers of shoddy products who are over enthusiastic about their product. Last, but not least, would be those who practice deliberate fraud and outright misrepresentation. Be sure and ask for proof that the product will perform as advertised. This proof could come from an independent laboratory or a university research program or study. Examine the warranty carefully and remember that according to the law the manufacturer must state that the warranty is limited or full in nature. How long does the warranty last and are parts, service, and labor included? Parts may be hard to obtain for some systems so be certain that the seller has strong experience in choosing compatible components. Be sure you will know specifically who will service the solar system if something goes wrong. Do not settle for a response that any plumber or handyman will be able to work on the solar system effectively. Don't try a do-it-yourself kit unless you have a very solid background as a home handy person. One or two mistakes could make a system inoperable and you will have no one to blame but yourself. Don't forget to use your local consumer office or your Better Business Bureau for help in determining whether a dealer is reputable or not. Check and see if there exists any local volunteer citizen solar organization around your area of residence.

Solar energy can also be applied to space heating needs also. The use of solar energy for the heating of space is quite promising. Over 20% of the energy used today is for the heating of space in residential situations. The requirement of more energy from the sun to

fuel the larger amounts of heat for space conditioning means more and better collection systems. Let's review some of the principles of solar collection since systems that require more heat utilize larger and more efficient collection means.

Any surface exposed to the sun will rise in temperature as it absorbs radiant solar heat. When surfaces become hotter than its surroundings it will begin to lose heat in three basic ways: First, by conduction, the movement to a different part of the heated object, second, by convection, through contact with something else such as air or water to transmit the heat elsewhere, last, by re-radiation to sky or surrounding cooler objects. The minimizing of heat losses and diverting heat to storage facility or radiator "solar collection" has in effect been accomplished. Certain other conditions must be met before useful amount of heat can be collected. The collector must be facing toward the sun and positioned at a tilt normal to the sun's rays. Finding the best angle to collect the maximum radiation possible is the objective. The conduction of heat from a surface to another medium where it can be easily stored must be both rapid and efficient. Also, the heat loss from the absorbing surfaces must be kept to a minimum to be efficient.

The flat plate type of solar collector absorbs both direct sunlight and diffuse solar radiation and collects heat even on cloudy days. The collector has three basic elements or parts: a transparent cover of glass or glass to permit the sun's rays to enter, absorbent type surface to collect the radiant energy from the sun, a heat transfer medium such as water or air to move the heat from collection to usage point. The covering increases the heat absorption of the

collection source greatly preventing heat losses by contact with the cooler outside air. There are available many different kinds and designs of collectors of varying cost and complexity. One type is the focusing collector that concentrates the sun's energy by means of mirror or lens. The ray's are reflected in a concentrated manner on an absorbent type surface. This type operates in the direct sunlight only and must be mounted so as to follow the sun as the earth moves. They can achieve temperatures of over 400° Fahrenheit. The focusing collector is currently quite expensive and not suitable for domestic use. They can be used to power steam generators or solar cookers and similar devices where high temperatures are desired. Usually one of two transfer methods are used, air or water. The method in which the surface of the collector absorbs solar energy is the major determinant of its efficiency as an absorbent surface. Certain selected surfaces have been developed to more readily reabsorb but slowly re-radiate heat. These surfaces consist of very thin, highly absorbent coating usually black metal oxide applied to a polished metal sheet.

The transparent cover on a collector serves as a protection against dirt and precipitation. It also is a barrier to heat loss by convection and thermal radiation. Both glass and transparent plastic film can be used as a covering material. Plastic is a relatively inexpensive method but has short lifetime and becomes less effective as transparency is reduced. Since plastic is made from hydrocarbons it is likely to become more expensive and less available in the future. Heat loss can be controlled by the use of selected kinds of glass coverings to retain heat within the collector. Some glass has a transmission value of up to 93% for solar wave length. Most standard

glass covers on units will transmit approximately 85% of solar radiation. Some units have a second glass cover if the selective surface is not used. The size of the air gap between the outer cover and the absorbent surface can affect heat loss and unit efficiency. A gap of 3/8 to 1/2 inch is optimum and anything greater allows more heat loss by convection. This heat loss by convection in some units can be reduced by replacing the air gap with a vacuum. This does add considerable cost to the unit, however.

Transfer of heat from collector to the point of ultimate use in the dwelling is another major element in solar systems. Water and air are the two most common heat transfer mediums used in flat plate solar collectors Water has a low ratio of volume to heat carrying capacity. There can be problems develop if leaks occur in pipework under strain due to temperature. Collectors using water as transfer medium consist of a series of metal tubes welded to or built into sheet metal absorber. Water flows through the tubes nd absorbs heat from the collector causing the transfer of energy to the source use. The water usually contains ethylene glycol to prevent freezing and to raise the boiling point.

Air transfer systems are much more bulkier and require larger ducts and heat exchange areas. More insulation is needed for an air system than in a water system. Natural circulation causes air to rise along the length of the air space assuming that the collector is on a slope or installed vertically. When this system is in the direct sun high air velocities will build up. The faster the air flow the lower the outlet temperature. To increase the temperature of the air in a collector the velocity must be reduced by slowing down the natural flow. This causes a kind of turbulence which brings interior air to

the surface where it can be warmed. This air system is less expensive and easier to construct for both the professional and domestic handy person. The real advantages of air systems in relation to water systems: First of all, freezing is not a problem and leaks are not as critical as with water, corrosion is also less of a problem and this type of system is the least expensive for the do-it-yourself type homeowner, rock storage type can act as its own heat exchanger as an additional advantage.

There are some disadvantages to air systems that are very important to consider when installing a system.

A major disadvantage is the slow water heating ability of air systems because of low load factor ability. There is a problem with air conditioning because it is not feasible with air charged systems. The air ducts for these systems are a disadvantage because of their large size requirements. Also, the fan horse power requirements are much higher for an air system in relation to liquid system. The rock storage on an air system can become loaded with dust unless special precautions are taken to clean the storage area.

The efficiencies of both air and water systems are quite good if the right choices are made in relative cost and ease of adaption to suit a particular dwelling needs.

The final basic component of a typical solar system is the storage unit for accumulated heat as needed for future use. The heat is drawn off when needed and accumulated during high solar radiation periods. A collector without a storage unit facility would be less efficient than an ordinary window at providing heat for immediate use.

A storage area must be large enough to provide three or four days'

supply in order to accomodate the potential successive days without sunshine. The ideal situation is to use the storage system to supply both the heat for a water heater and space heating requirements.

The collection and storage of heat is a dynamic process. Collection from the system will vary from day to day and hour to hour. The system must be equipped with a reliable thermostatically controlled set of valves or dampers which will ensure that heat which is collected during a heating cycle will be preserved during a non-heating time. The system must be equipped so that the collection system will be in a heating mode prior to circulation of the fluid through the collector by the pumps or blowers.

It is imperative that the system be sized according to the size and construction of the building or water heater to be served. A system which is too large will require more capital and necessitate a longer pay-back time in order for the savings in energy cost to offset the original purchase price. However, if too small a system is installed, a lower amount of energy savings may be realized.

The size and type of storage must also be considered so that the collection system will be matched with the collection system. If too small a liquid storage is installed, boiling may occur, whereas if too large a tank is used, the liquid temperature may not reach a high enough amount to be usable for water or space heating.

With a rock storage system too small a storage may result in more loss of heat in the storage from conduction. Too large a rock storage may result in a low rock storage temperature which may not be usable as water or space heating.

Any kind of storage system must attain a temperature higher than that which it is to heat or little value will result from the storage of the low level heat.

PASSIVE SOLAR SYSTEMS

A less expensive and perhaps better way to take advantage of the solar energy for space heating is by using a Passive Solar System. The basic idea in respect to this system is that no expensive pumps, collectors, and controls are involved. The system consists of glass oriented toward the sun so that the rays will penetrate the glass during the winter months but is protected by an overhang or cover during the summer months. The basic theory with this system is that the sun's rays pass through the glass and warms the surface which it strikes. To moderate the temperature or to store heat when the sun's rays are very hot and to radiate heat when the rays no longer penetrate the glass, a large mass of masonry or a water wall is built just inside the glass enclosure. This wall is called a trombe or thermal storage wall after a designer from France who is given the credit for originally designing a structure to accomplish the use of the sun by this system.

The passive system of glass wall can be constructed as a greenhouse, as a large glass area on the south side of a residence or it can be glass panels placed above the attic space of a structure when hot air may be collected and returned to the living area. Many different designs have been utilized with a number of reports of favorable response to the systems.

The passive system does not use a storage system other than the Trombe wall as mentioned earlier.

AUXILIARY ENERGY SYSTEMS

Any solar system in this particular geographic area will require a system to supplement the output from the solar system. This system may be fueled with wood, oil, gas or may require electric energy during times of extreme cold or long cloudy winter days. This system should be sized large enough to provide the heat energy necessary to heat the water or space should the solar system fail.

This requirement of an auxiliary energy system also increases the cost of a solar installation. This must also be considered when attempting to compute the pay-out time for a solar heating system.

SUMMARY

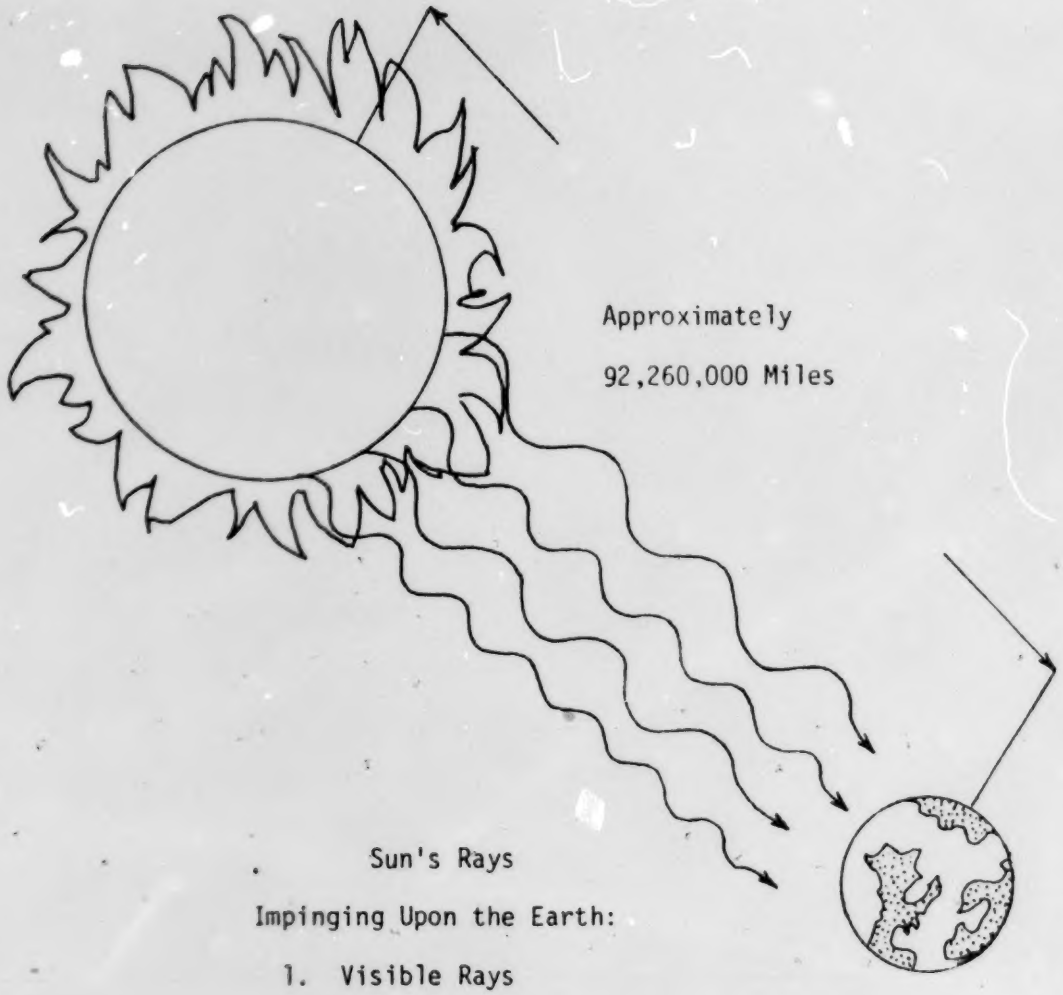
Solar collection equipment is being marketed and installed on an increasing number of residences. These installations will require persons to service them who are knowledgeable in solar collection systems and who are dedicated to the use of solar system as an energy conservation device rather than as a source of cheap energy. In the solar energy system as in any other system, there are no "free lunches". The energy may be free but the collection system requires an outlay of money in order to have a good, efficient, maintenance free system. The system must be service efficient or the cost of repairs and labor for repairs will outweigh the savings gained from the free energy.

Emanation of Rays from the Sun

The sun's surface is approximately 6000° K or approximately 10,000° F.

The sun is the source of all energy:

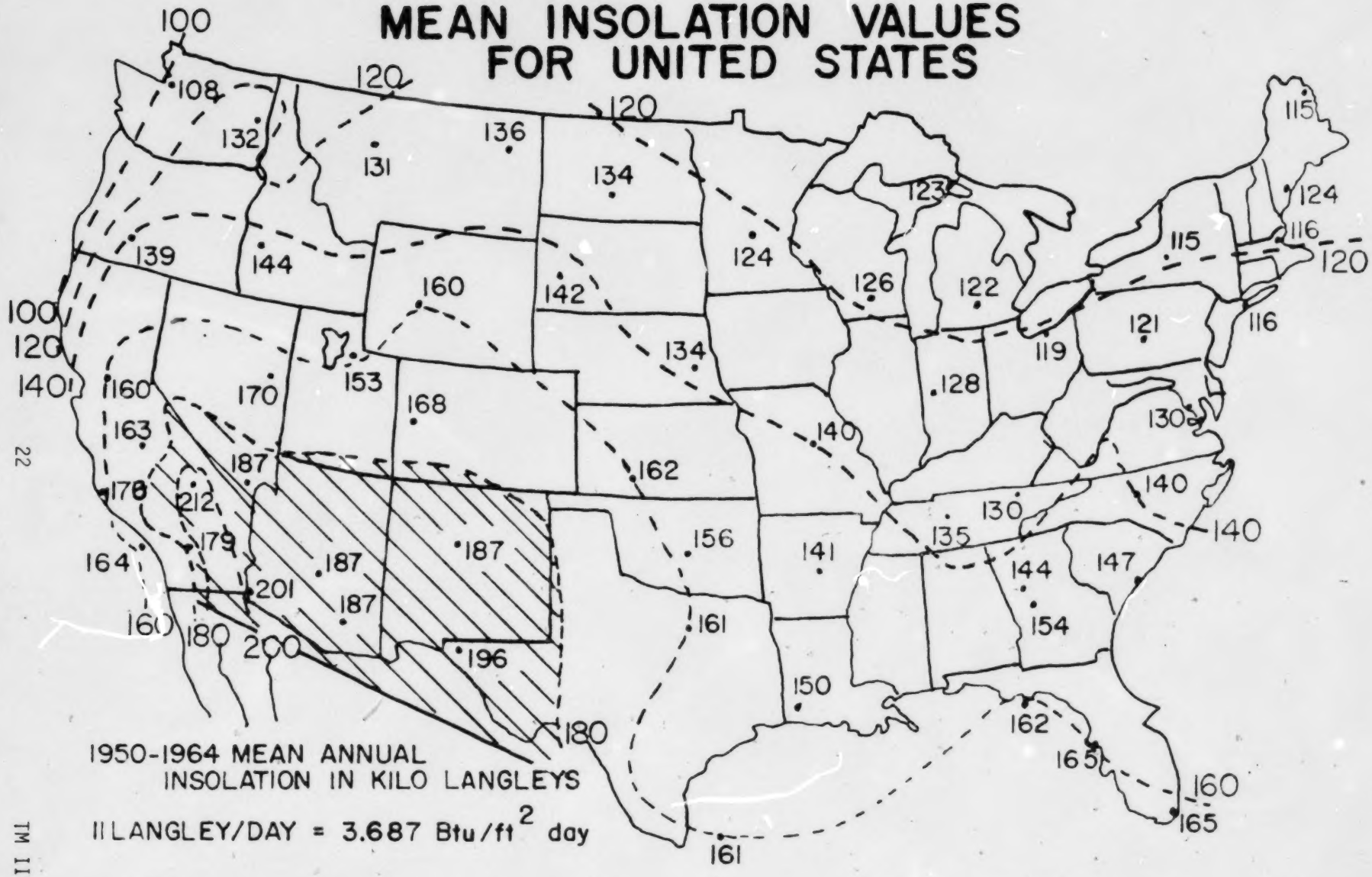
1. solar
2. wind
3. fossil
4. hydro



Sun's Rays

Impinging Upon the Earth:

1. Visible Rays
2. Ultraviolet Rays
3. Infrared Rays


MEAN INSOLATION VALUES
FOR UNITED STATES
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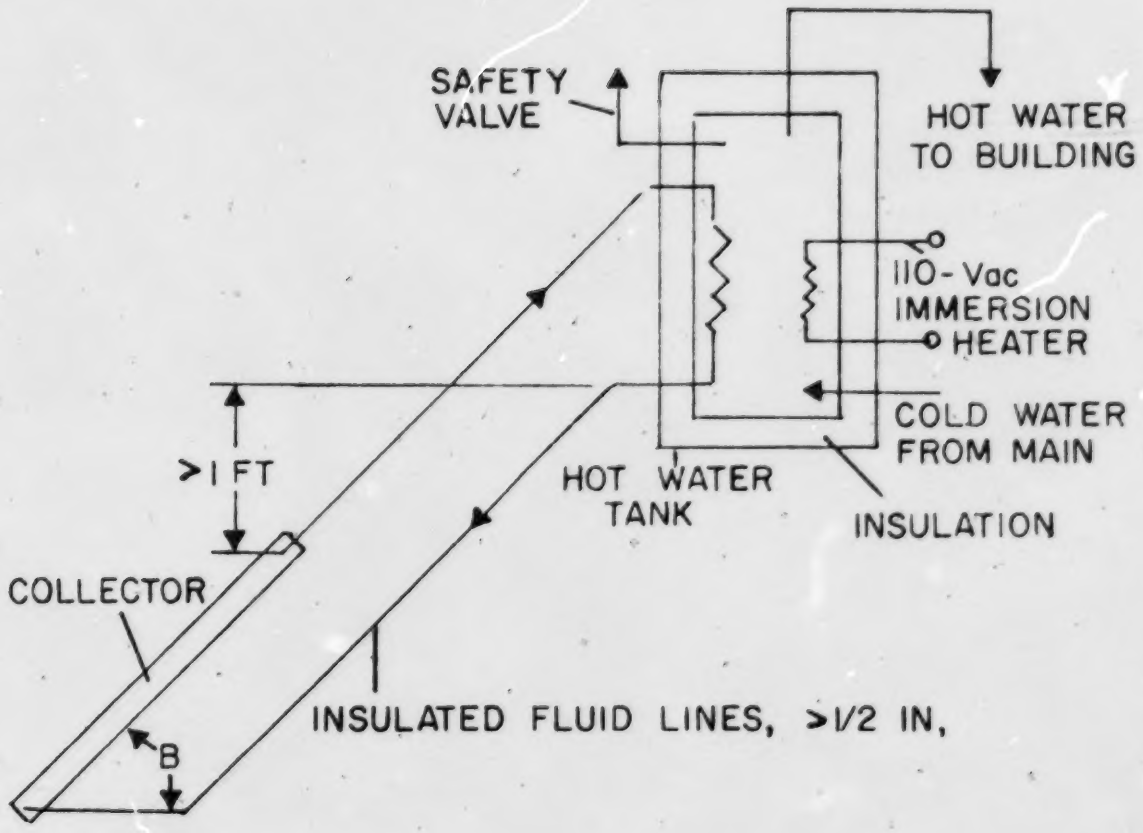
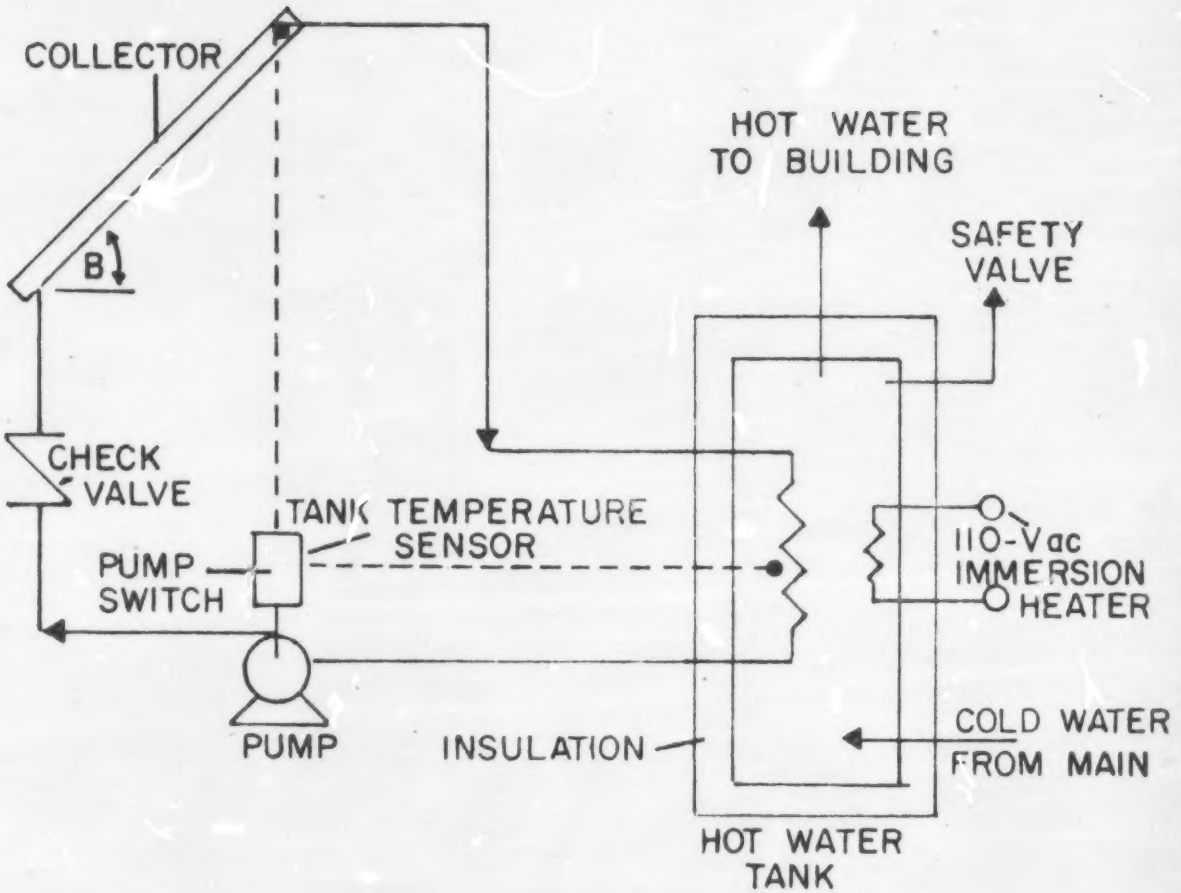
INSOLATION IN KILO LANGLEYS
1 LANGLEY/DAY = 3.687 Btu/ft2 day

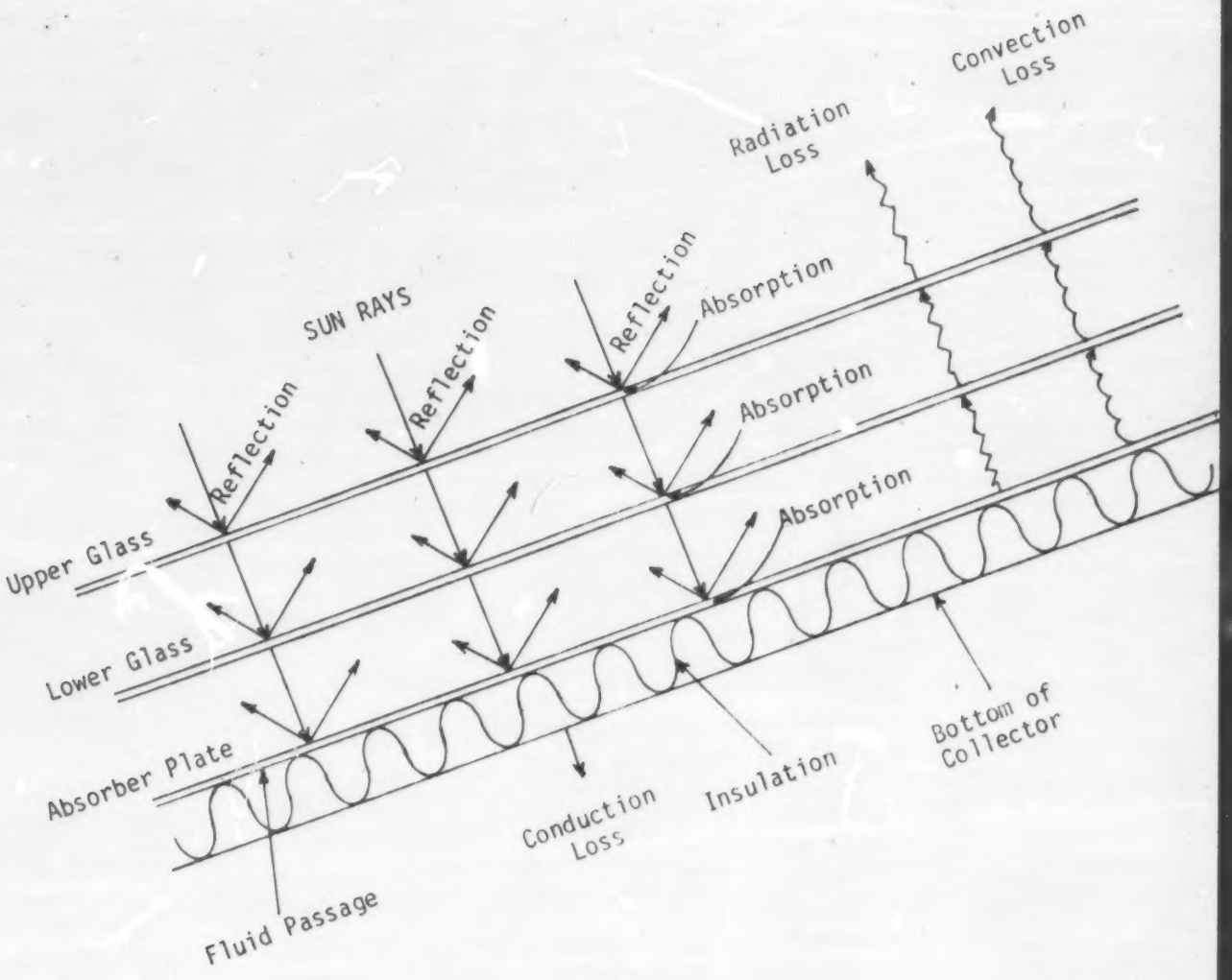
TYPICAL THERMOSYPHON CIRCUIT



FORCED CIRCULATION SYSTEM



SUN'S RAYS STRIKING ABSORBER PLATE



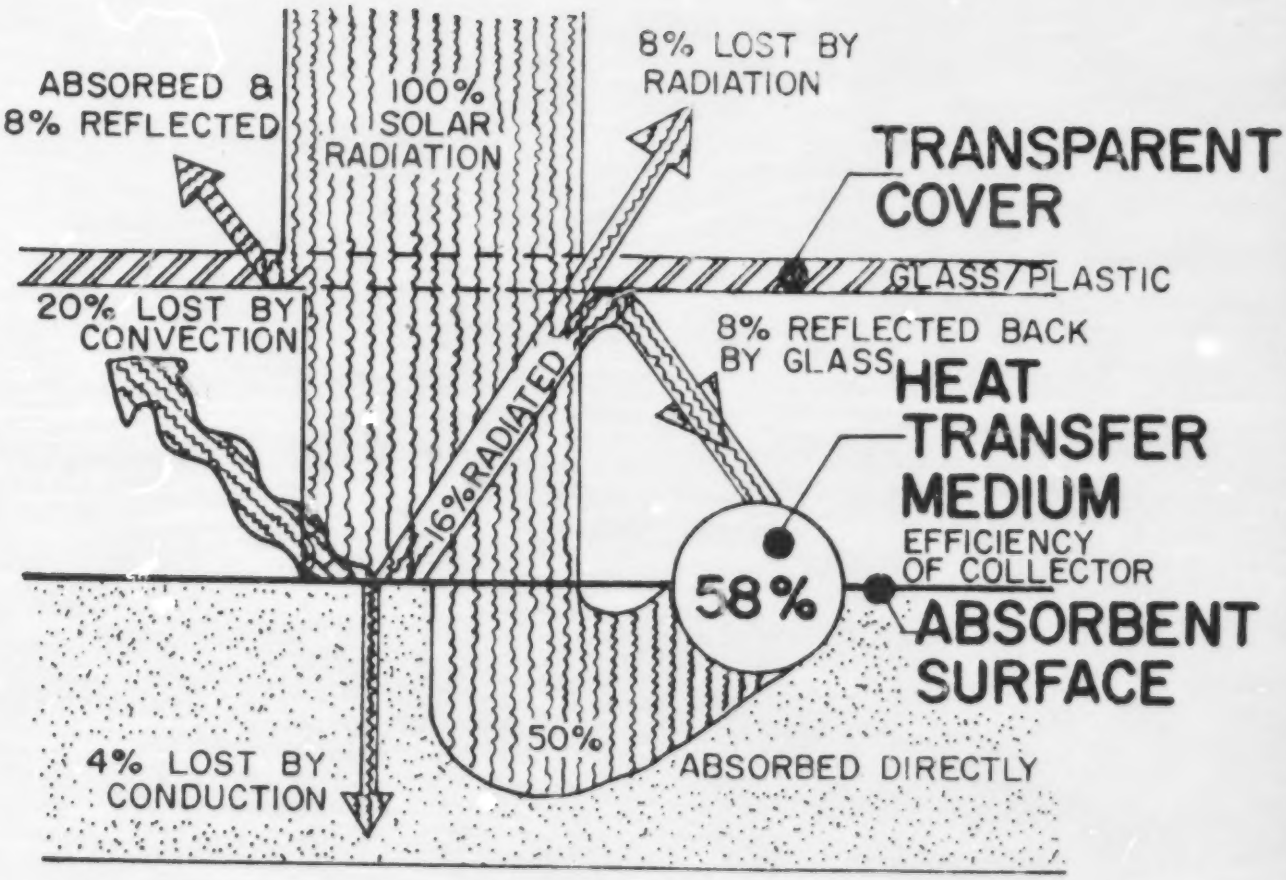
SKETCH OF COLLECTOR DEPICTING:

A. Absorption by collector

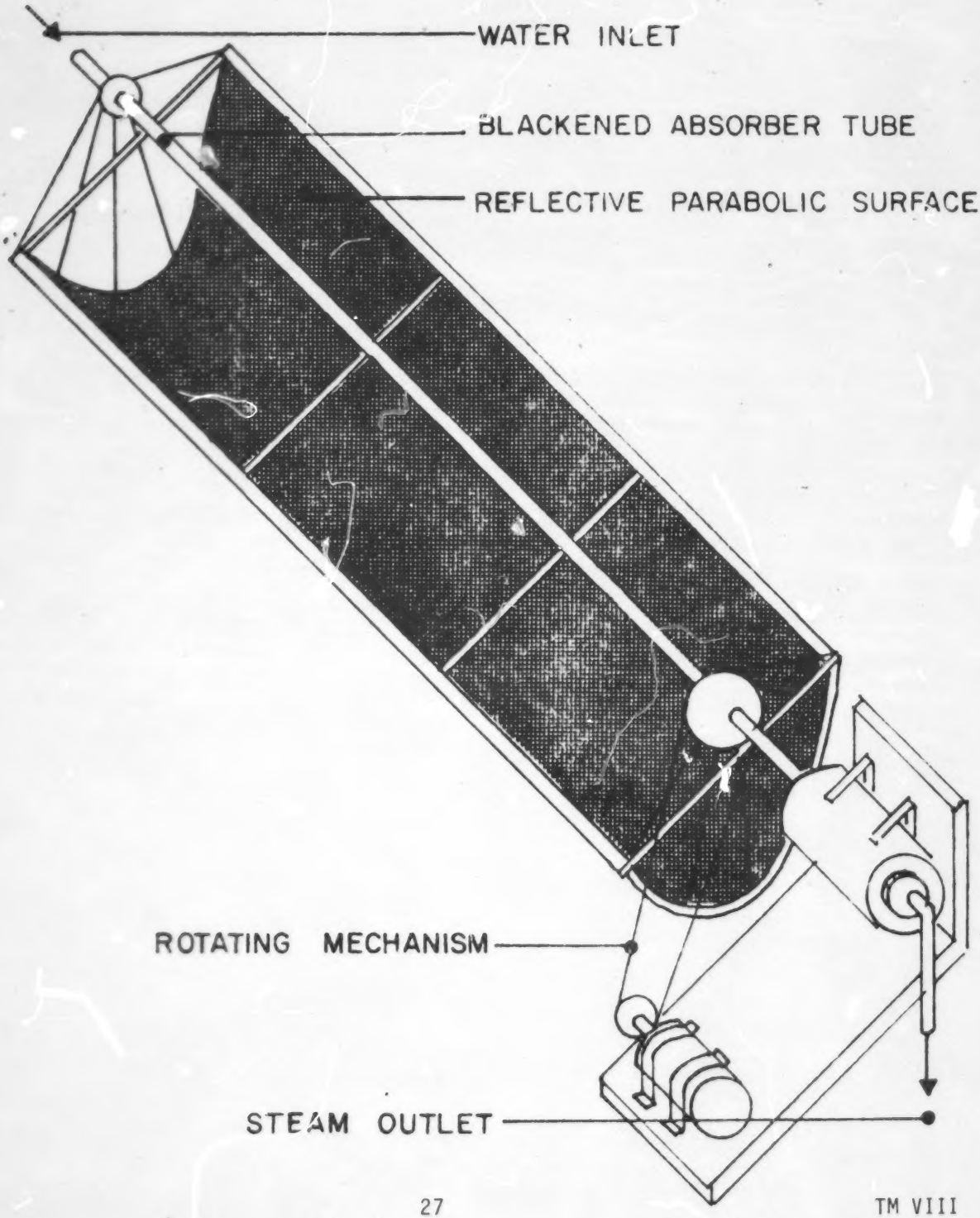
B. Losses

1. Reflection
2. Conduction
3. Convection
4. Radiation

RADIATION DISTRIBUTION IN TYPICAL LIQUID TYPE SOLAR COLLECTOR



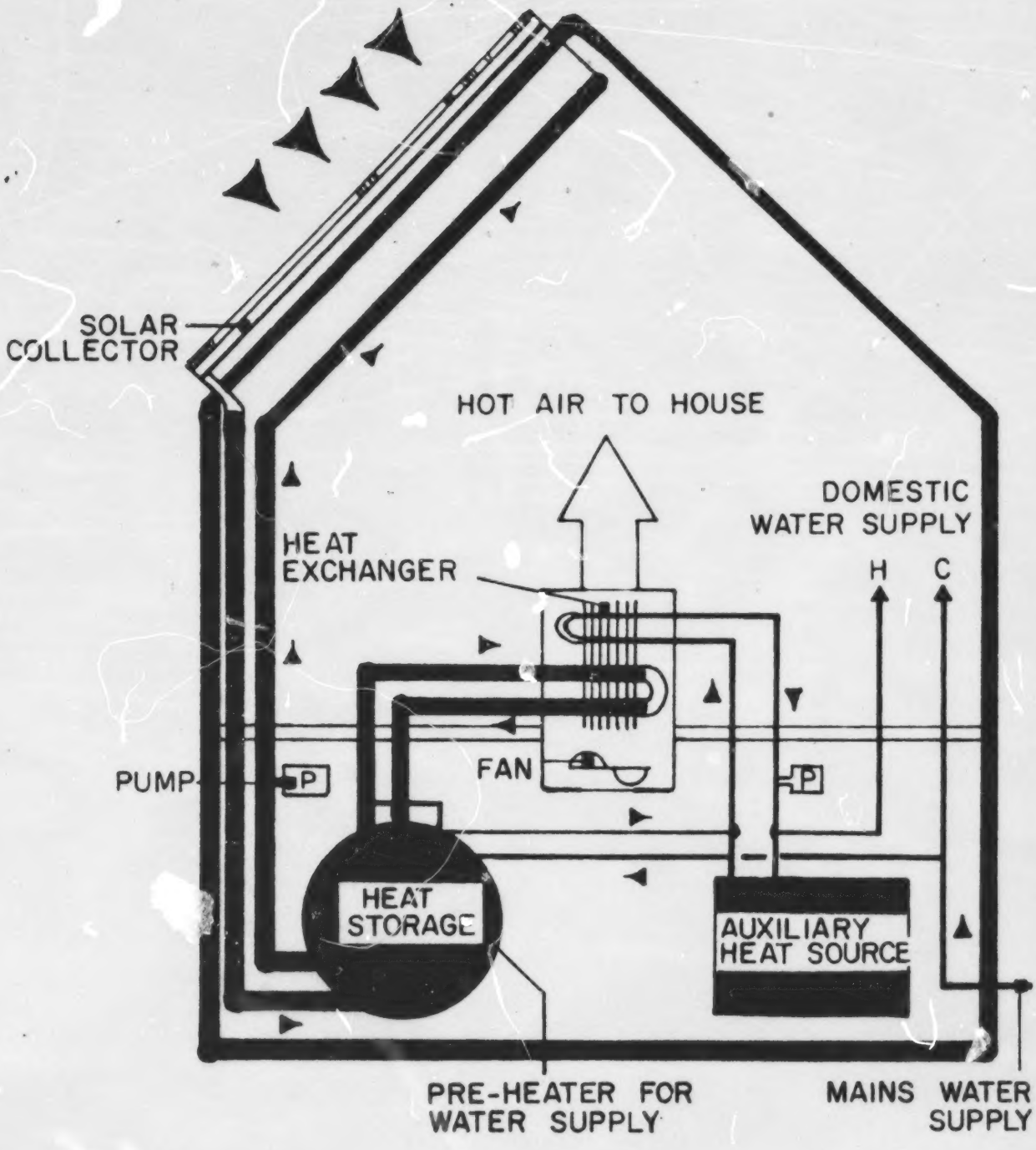
FOCUSING COLLECTOR



27

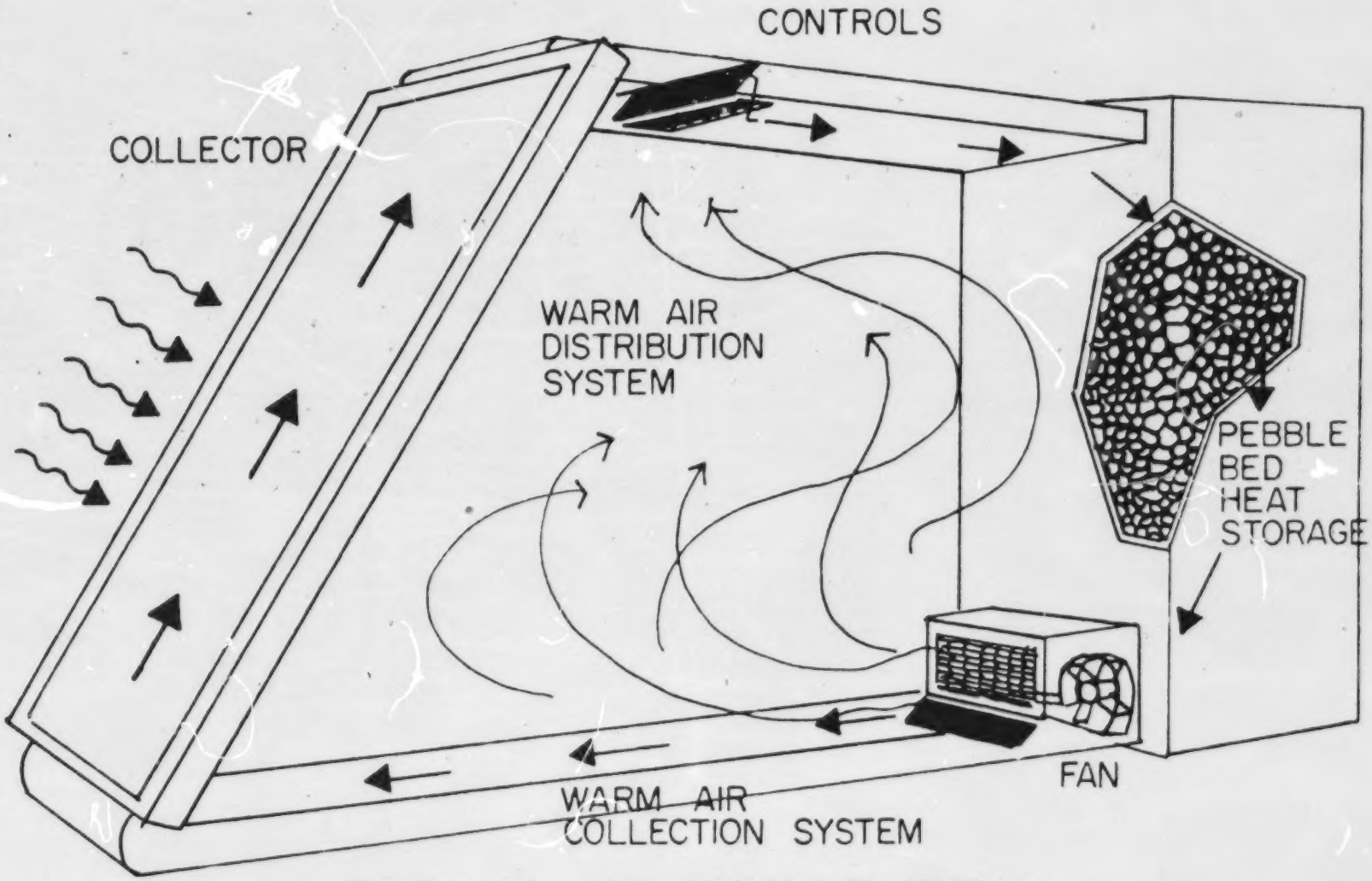
TM VIII

SIMPLE SOLAR HEATING SYSTEM



28

TM IX



29

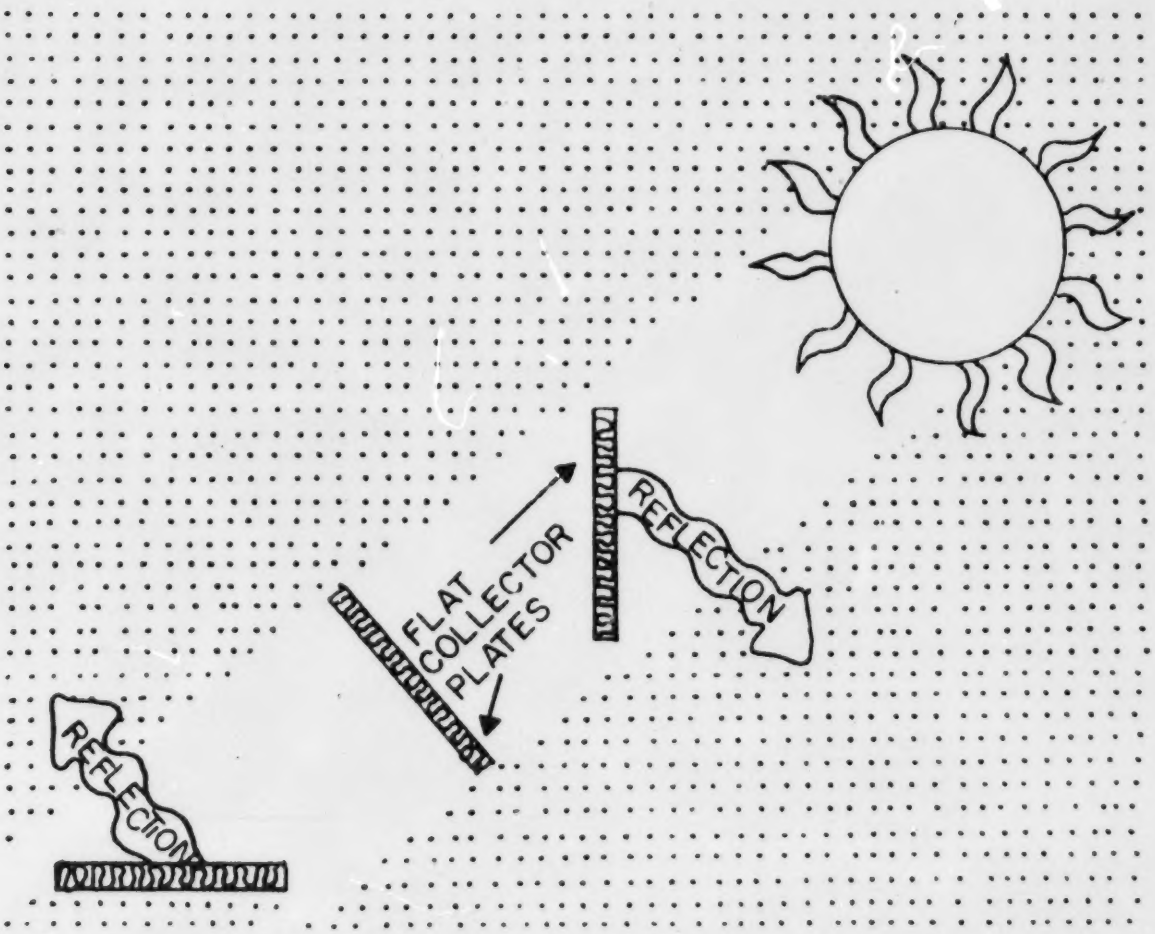
TM X

FORCED AIR DISTRIBUTION THROUGH PEBBLE BED STORAGE SYSTEM

32

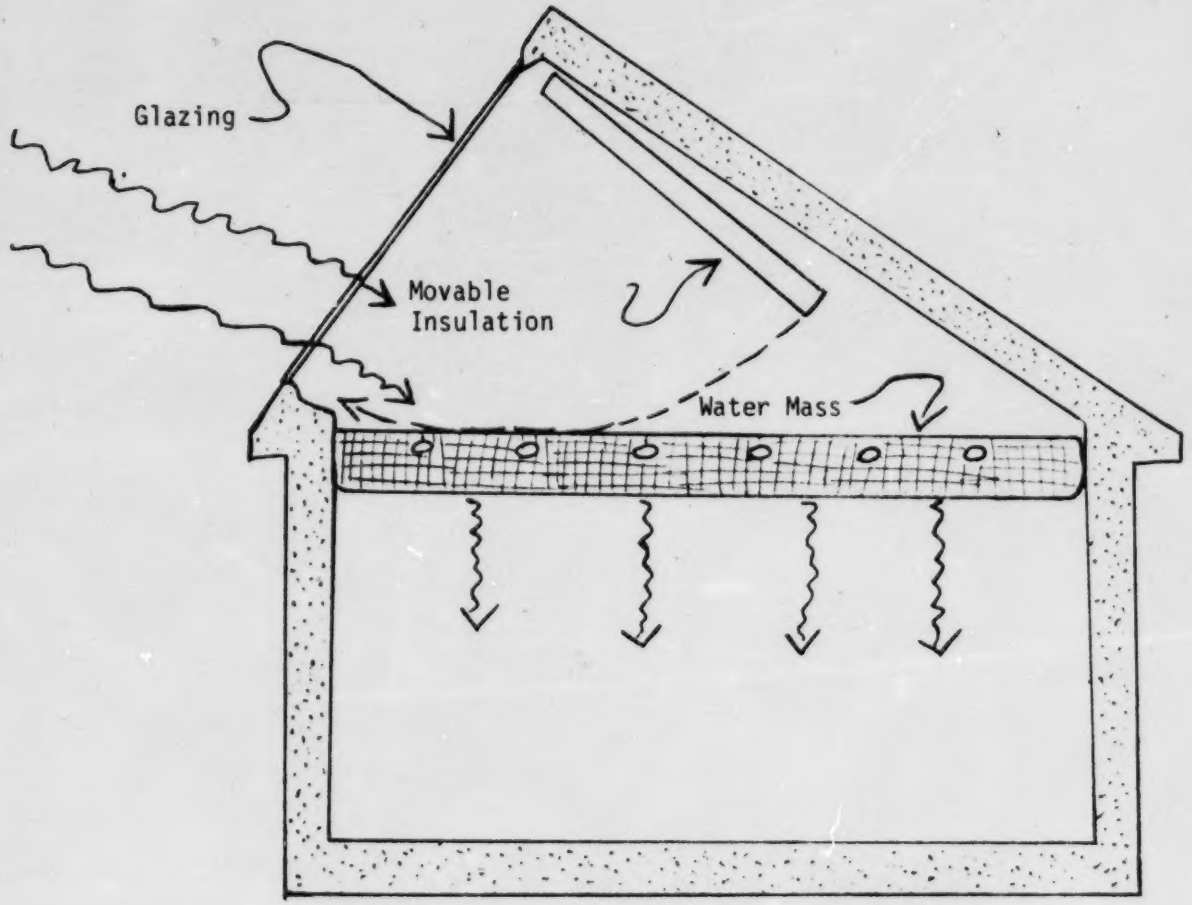
33

RELATIONSHIP OF COLLECTION EFFICIENCY TO ANGLE OF INCLINATIONS

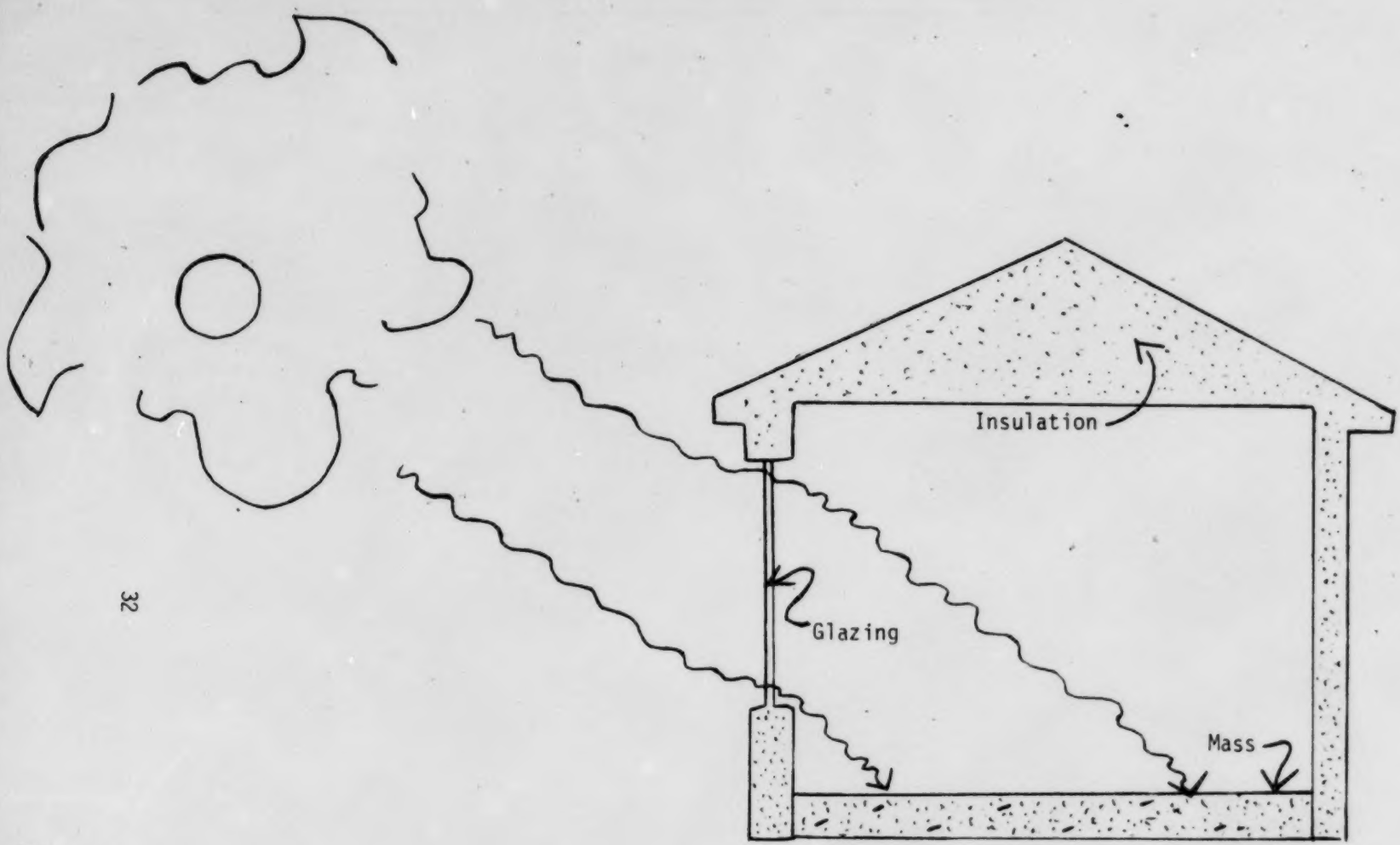


THE LOSS IN COLLECTION EFFICIENCY AS THE COLLECTOR IS TILTED AWAY FROM THE OPTIMUM ANGLE OF INCLINATION (WHICH DEPENDS ON THE LATITUDE OF THE SITE).

PASSIVE SOLAR HEATING



Thermal storage material can also be placed horizontally. Movable insulation limits heat loss; living spaces are heated by radiation from overhead.

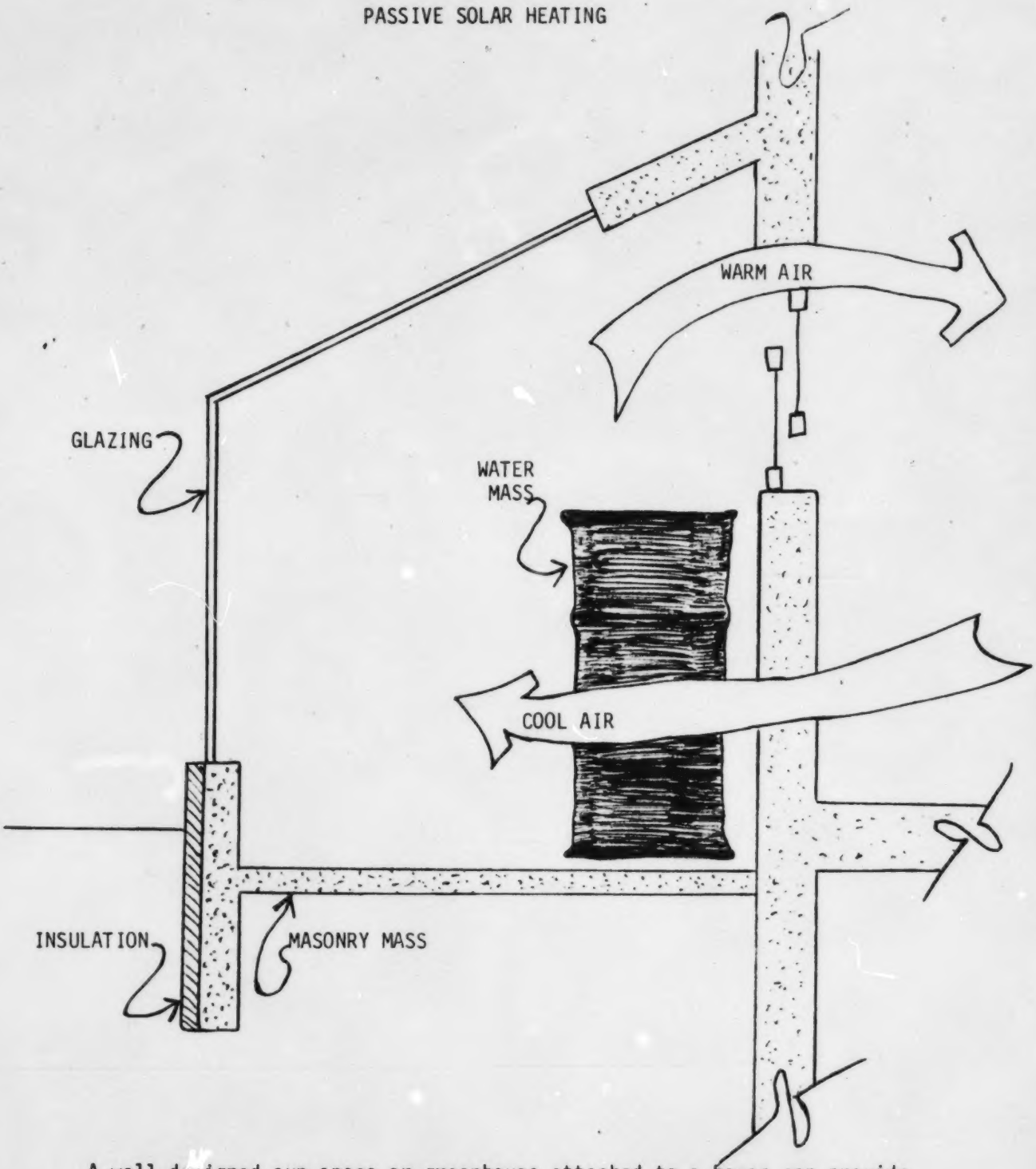


32

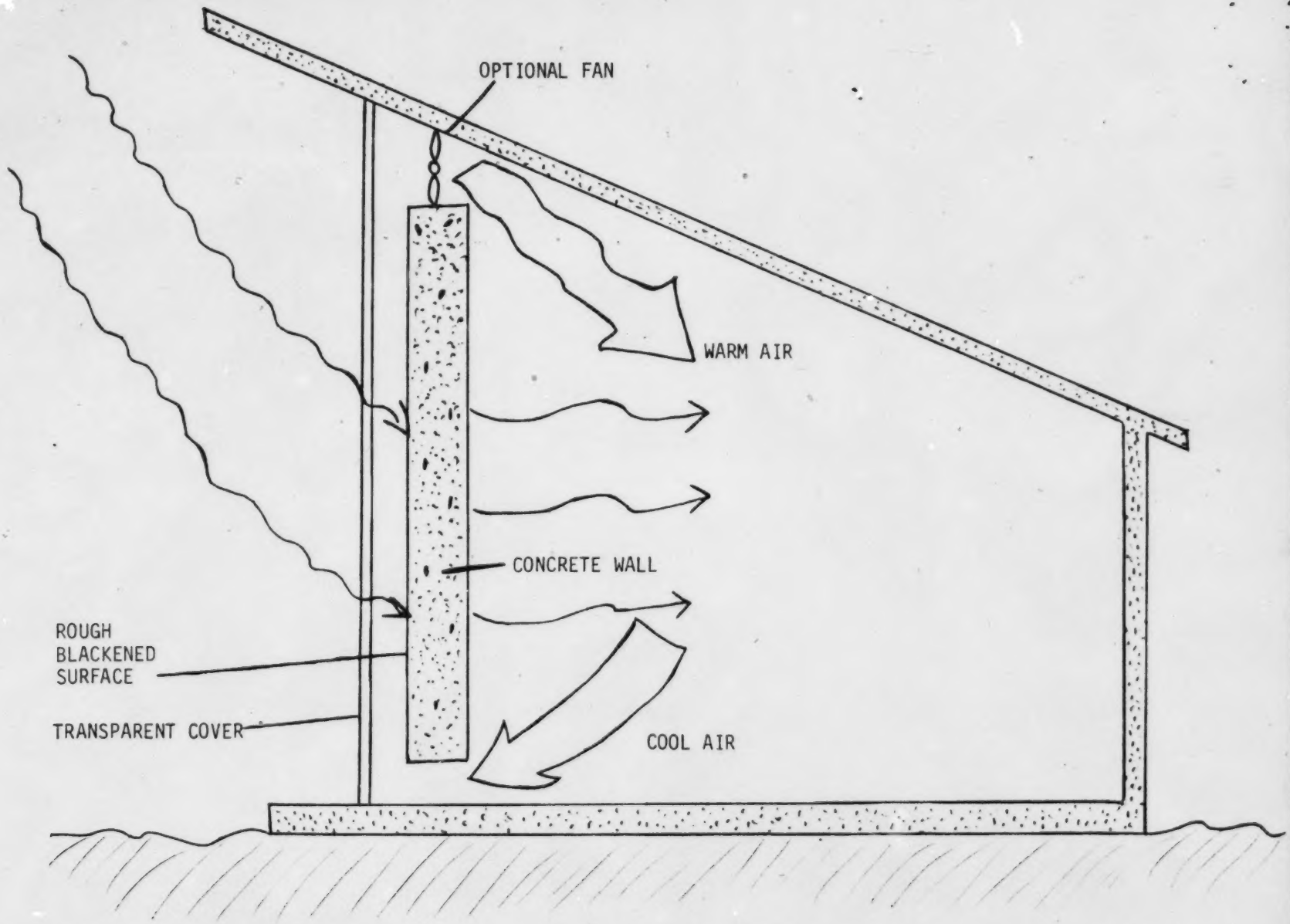
PASSIVE SOLAR HEATING

The most widely used form of passive solar heating is sunlight entering through glass, direct gain. Even non-solar houses use it. Heavy building materials can store it.

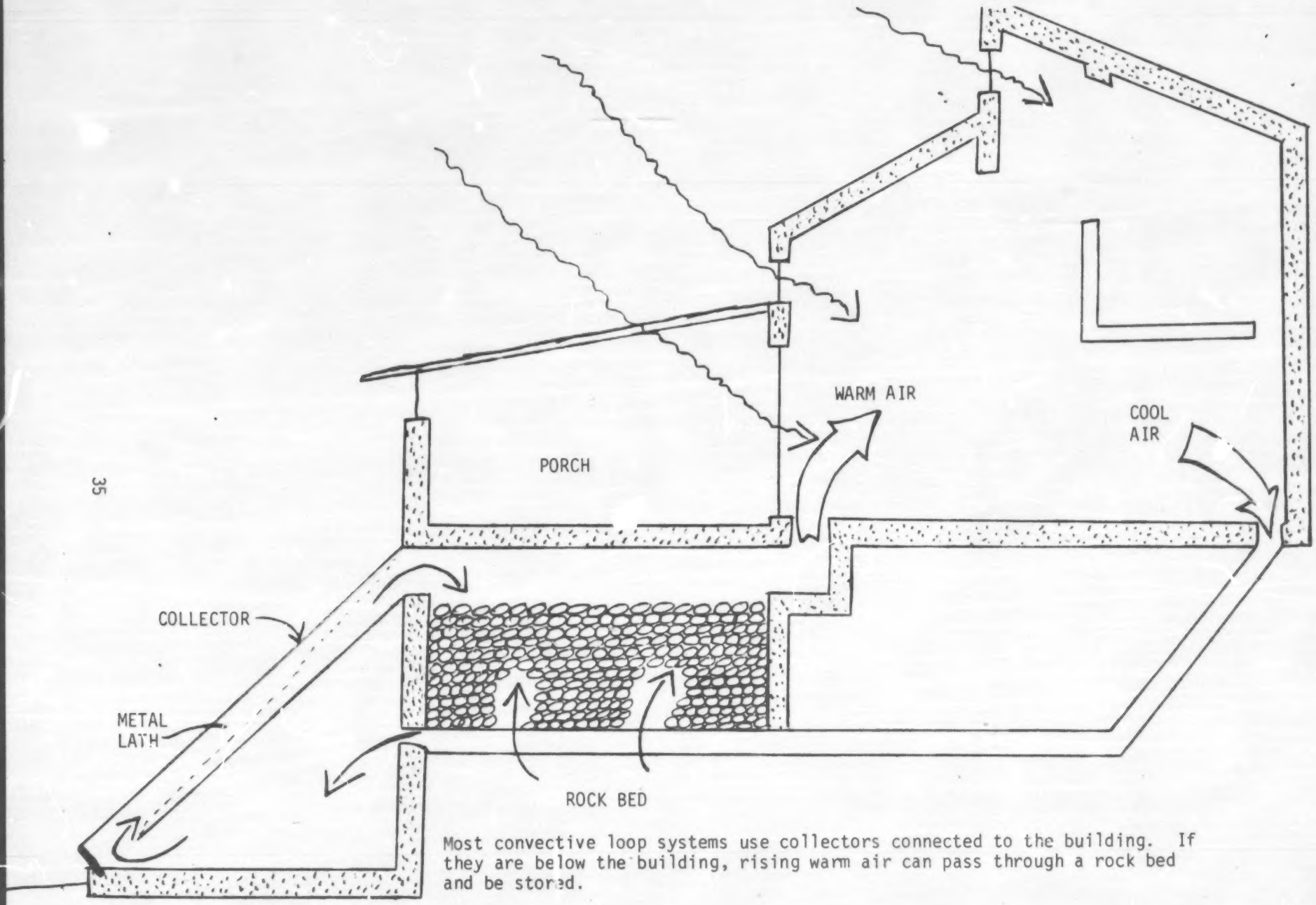
PASSIVE SOLAR HEATING



A well-designed sun space or greenhouse attached to a house can provide considerable heat with proper management. It can reduce heat loss --- and help grow plants as well.



When heavy building materials behind the windows catch the sun --- Trombe, or thermal storage walls --- warmth is slowed for nighttime delivery, smoothing temperatures.



Most convective loop systems use collectors connected to the building. If they are below the building, rising warm air can pass through a rock bed and be stored.

SOLAR ENERGY USAGE

TEST

I. Indicate correct response to statements below by circling "T" for those statements that are true and "F" for those statements that are false.

T F 1. Solar heating can effectively provide all of the space heating needs of a family.

T F 2. Solar energy has only recently come into use by mankind.

T F 3. Solar energy itself is free for the taking.

T F 4. Estimated amounts of solar energy striking the atmosphere of the earth is far beyond the current needs of man.

T F 5. The amount of solar radiation striking the earth is constant.

T F 6. Conditions that are favorable for greatest amount of radiation to strike surface of the earth are found on clear days at low latitudes around noontime.

T F 7. Domestic water heating is considered to be one of the most successful small scale uses of solar energy.

T F 8. From the standpoint of energy consciousness the "free" system of water heating is more economical to operate than is the "forced" system.

T F 9. It is advisable to utilize some non-freezing heat transfer fluid in heating systems to prevent water from freezing during winter months.

T F 10. Heat produced from most solar water heating systems is considered to be low-grade heat.

T F 11. Reverse cycling in solar water heating systems occurs when circulation fluid loses energy at night through the collector.

T F 12. Evaluation factor of commercial solar energy systems factors include cost, efficiency, and warranty considerations.

T F 13. Space heating by use of solar energy has possible future for significant reduction of residential energy costs.

T F 14. Whenever a surface is exposed to the sun it will rise in temperature as it absorbs radiant heat.

T F 15. Northern exposures are excellent positions for establishing solar collectors.

T F 16. Focusing collectors are suitable for domestic use because they are capable of temperatures over 400^{0} Farenheit.

T F 17. Focusing collectors differ from flat plate collectors in that they operate in direct sunlight only.

T F 18. Efficiency of a solar collector is highly influenced by the way in which the collector absorbs solar energy.

T F 19. A major function of the transparent cover on the solar collector is to serve as a protective barrier against dirt and precipitation.

T F 20. The two most frequently used heat transfer media are water and air.

T F 21. Wind blowing across the surface of the solar collector will not reduce efficiency of the collector.

T F 22. Clouds have little effect upon the amount of energy that solar collectors absorb in a given time period.

T F 23. Some systems utilize small pebbles and cinder blocks as storage media for solar systems.

T F 24. Solar systems that provide 40 to 70 percent efficiency are considered high quality efficiency systems.

T F 25. The majority of the United States lies within the range of possible solar-energy implementation.

T F 26. Energy conservation measures can be reduced in housing with solar systems because solar energy is free.

T F 27. Windows that have a southern exposure act as solar collectors themselves.

T F 28. Angle of solar collector's position has little effect upon its total efficiency.

T F 29. A greenhouse on the southern exposure of a building can act as a passive solar system.

T F 30. A Trombe wall can be constructed within a structure to serve as a moderating system.

II. Match the terminology listed at the right with the correct statement below by putting the correct letter in space provided at the left of statement.

_____ 31.	Rate at which solar energy is received on horizontal surface.	A. Insolation
_____ 32.	Conventional measure of solar radiation equal to 4 BTU's per square foot.	B. Convection
_____ 33.	Transfer of heat by circulation of liquid or gas	C. Thermostatic Control
_____ 34.	Liquid used to transfer thermal energy	D. Heat transfer fluid
_____ 35.	Device for transferring thermal energy from one fluid to another.	E. Throm
_____ 36.	Heat processed by material resulting from motion of molecules which can do work	F. Solar constant
_____ 37.	Measurement of average intensity of solar energy at outer limits of atmosphere	G. Thermal energy
_____ 38.	Heating system used to provide space heat or domestic hot water during times of low solar collection.	H. Heat exchanger
_____ 39.	Device for recording the state of the system and controlling the pumps, valves, dampers, and blowers on an active solar system.	I. Auxillary
_____ 40.	A massive wall of brick, concrete or water used to store heat and moderate the temperature in a passive solar system.	J. Langley
		K. Collector

41. There are three means by which heat is transferred from one medium to another. What are these three as discussed in the unit?

A.

B.

C.

SOLAR ENERGY USAGE

TEST ANSWERS

I. True - False

1. F	16. F
2. F	17. T
3. T	18. T
4. T	19. T
5. F	20. T
6. T	21. F
7. T	22. F
8. T	23. T
9. T	24. T
10. T	25. T
11. T	26. F
12. T	27. T
13. T	28. F
14. T	29. T
15. F	30. T

II. Matching

31. A	36. G
32. J	37. F
33. B	38. I
34. D	39. C
35. H	40. E

41. Three means by which heat is transferred between one medium and another include:

A. Conduction

B. Convection

C. Re-radiation